REMARKS

Claims 17-36 are presently in the application. Claims 1-16 have been canceled. Claims 21-23 have been withdrawn.

Claims 17, 19, 20, 31, 32 and 34 have been amended as suggested by the examiner to overcome the objection to the claims.

Claims 17, 18, 23, 25, 26, 31, 32 and 34 have been rejected under 35 U.S.C. 102 as anticipated by Khair et al. (US 6,293,096). Reconsideration of the rejection is respectfully requested.

To support a rejection of a claim under 35 U.S.C. 102(b), it must be shown that each element of the claim is found, either expressly described or under principles of inherency, in a single prior art reference. See Kalman v. Kimberly-Clark Corp., 713 F.2d 760, 772, 218 USPQ 781, 789 (Fed. Cir. 1983), cert. denied, 465 U.S. 1026 (1984).

Khair teaches an aftertreatment system 8 including a first stage 10 comprising an oxidation catalyst 14, a second stag 20 comprising a NO_x trap and a third stage 30 comprising a carbon trap oxidizer.

Applicants' claim 17 is directed to an exhaust-gas cleaning system for cleaning the exhaust gas of an internal combustion engine comprising, inter alia, "at least one device, disposed downstream of the oxidizing catalytic converter for the selective catalytic reduction of the exhaust gases." Applicants' claim 31 is directed to a method for cleaning exhaust gases of an internal combustion engine including, inter alia, the step of "passing an exhaust-gas stream . . .

through at least one device, downstream of the oxidizing catalytic converter, for selective catalytic reduction."

A device for the selective catalytic reduction of the exhaust gases (i.e., a SCR catalyst) is not the same thing as a NO_x trap or a carbon trap oxidizer. As evidence of this fact, enclosed are excerpts from "dieselnet.com" discussing NO_x traps, SCR catalysts and particulate filters.

Khair does not teach an exhaust-gas cleaning system for cleaning the exhaust gas of an internal combustion engine comprising a SCR catalyst or any device for the selective catalytic reduction of the exhaust gases downstream of an oxidizing catalytic converter as required by claim 17 or a method for cleaning exhaust gases of an internal combustion engine including the step of passing an exhaust-gas stream through at least one device, downstream of an oxidizing catalytic converter, for selective catalytic reduction, as required by claim 31. Thus, Khair does not anticipate either claim 17, 31 or the claims dependent thereon.

Further, claim 17 requires a delivery device, <u>integrated with the at least one oxidizing catalytic converter</u>, for delivering a reducing agent into the exhaust-gas stream of the engine, the delivery device including <u>a recess or a drilled-out opening in the oxidation catalytic converter</u> whereby the reducing agent can reach the exhaust stream without coming into contact with the oxidation catalytic converter.

Claim 31 requires the step of delivering a reducing agent to the exhaust-gas stream <u>inside the at least one oxidizing catalytic converter</u>, the delivery being effected inside the oxidation catalytic converter whereby the reducing agent can reach the exhaust gas stream <u>via a recess or</u>

a drilled-out opening in the oxidation catalytic converter without coming into contact with the oxidation catalytic converter.

In Khair, the HC fuel injector 40 is not integrated with the at least one oxidizing catalytic converter, because, in Khair, the HC fuel injector 40 is located downstream of the oxidation catalyst 14. Further, there is no teaching in Khair that the delivery device includes a recess or a drilled-out opening in the oxidation catalytic converter. For these additional reasons, Khair does not anticipate claim 17.

Khair, also, does not teach the step of delivering a reducing agent to the exhaust-gas stream inside the at least one oxidizing catalytic converter, the delivery being effected inside the oxidation catalytic converter whereby the reducing agent can reach the exhaust gas stream via a recess or a drilled-out opening in the oxidation catalytic converter without coming into contact with the oxidation catalytic converter. Thus, for this additional reason, Khair does not anticipate claim 31.

An object of applicants' invention is to reduce the overall length of an aftertreatment system based on selective catalytic reduction. Spec., p. 2, l. 19 through p. 3, l. 10. Khair provides no teaching or suggestion of how one of ordinary skill in the art would accomplish this object. Khair shows a system based on NO_x and particulate trapping. Khair injects HC downstream of the oxidation catalytic converter 14, not within the oxidation catalytic converter. Khair wants to achieve a maximum effect by injecting HC in the peripheral zones so that the HC cannot pass hole 24, but effectively regenerates the lean NO_x trap (LNT) 22. If Khair were to integrate the HC

injection within the oxidation catalytic converter 14, he would lose HC through bypass hole 24

of the lean NO$_x$ trap. That is, Khair leads away from applicants' invention not only because it

deals with a different system (NO$_x$ trapping versus SCR), but also because of a different system

setup. Fig. 2 of Khair even shows injection far downstream of the oxidation catalyst 114, even

after the exhaust gases have already passed carbon trap oxidizer 132.

Claims 19, 20, 24 and 27 have been rejected under 35 U.S.C. 103 as unpatentable over

Khair et al. in view of Oshima et al. (US 5,412,946). Claims 28-30, 35 and 36 have been rejected

under 35 U.S.C. 103 as unpatentable over Khair et al. in view of Daetz et al. (US 6,880,328).

Reconsideration of the rejections is respectfully requested.

To establish prima facie obviousness of a claimed invention, all the claim limitations

must be taught or suggested by the prior art. In re Royka, 490 F.2d 981, 180 USPQ 580 (CCPA

1974).

Neither Oshima et al nor Daetz et al teaches or suggests a SCR catalytst or any device for

the selective catalytic reduction of the exhaust gases downstream of an oxidizing catalytic

converter as required by claim 17 or a method including the step of passing an exhaust-gas

stream through at least one device, downstream of an oxidizing catalytic converter, for selective

catalytic reduction, as required by claim 31.

Further, there is no teaching in either Oshima et al or Daetz et al of a delivery device

including a recess or a drilled-out opening in the oxidation catalytic converter or of the step of

delivering a reducing agent to the exhaust-gas stream inside the at least one oxidizing catalytic
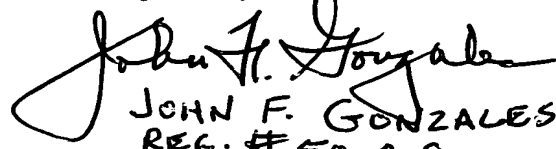
converter, the delivery being effected inside the oxidation catalytic converter whereby the

reducing agent can reach the exhaust gas stream <u>via a recess or a drilled-out opening in the</u>

<u>oxidation catalytic converter</u> without coming into contact with the oxidation catalytic converter.

Since neither Oshima et al nor Daetz et al solves the basic deficiencies of Khair noted

above, even if it were obvious to combine the teachings of Khair et al and Oshima et al or of

Khair and Daetz et al one of ordinary skill in the art would not have arrived at the subject matter

claimed by the applicants' in claims 19, 20, 24, 27, 28-30, 35 and 36.

Entry of the amendment and allowance of the application are respectfully requested.

Respectfully submitted,

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Enclosure: Excerpts from "dieselnet.com"

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Encl. 1: Catalyst Systems (--> Nox traps)

NO_x adsorber systems generally consist of a conventional three-way catalyst which additionally incorporates NO_x storage components. These storage components in NO_x adsorbers are typically compounds of the following elements

> o Alkaline earths—barium (Ba), calcium (Ca), strontium (Sr), magnesium (Mg)
> o Alkali metals—potassium (K), sodium (Na), lithium (Li), cesium (Cs)
> o Rare earth metals—lanthanum (La), ytrium (Y)

Source of information: http://www.dieselnet.com/tech/cat_nox-trap.html

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Encl. 2: Types of SCR Catalysts

Overview

Selective catalytic reduction of NO_x with ammonia was first discovered over a platinum catalyst [Heck 1995]. The Pt technology can be used only at low temperatures (< 250°C), due to its poor selectivity for NO_x reduction at higher temperatures. Two groups of base metal SCR catalysts—vanadia and zeolite based—were later developed, which can operate at higher temperatures and have wider temperature windows, as illustrated in Figure 4.

Figure 4. Operating Temperature Windows for Different SCR Catalysts

Platinum catalysts lose their NO_x reduction activity above approximately 250°C. A V_2O_5/Al_2O_3 catalyst was used first for higher temperature applications. However, its use was limited to sulfur free exhaust gases because the alumina reacted with SO_3 to form $Al_2(SO_4)_3$, resulting in catalyst deactivation. To solve this problem, a nonsulfating TiO_2 carrier was used for the V_2O_5, which then became the catalyst of choice. These catalysts functioned at higher temperature and over a broader temperature range than Pt. Other base metal oxides, such as tungsten trioxide (WO_3) and molybdenum trioxide (MoO_3), are often added to V_2O_5 as promoters to further decrease the SO_3 formation and to extend catalyst life.

The upper temperature limit of vanadia catalysts—about 450°C—is still insufficient for certain hot gas applications, such as gas-fired cogeneration plants. Zeolite based catalysts have been developed and commercialized in the 1990s that function at higher temperatures. Finally, ion-exchanged zeolites of greatly improved low temperature activity (at the expense of a reduced upper temperature limit) have been developed for mobile applications. The operating temperature ranges for different SCR catalyst technologies are shown in Table 3. These temperature ranges should be considered approximate. Catalysts are under development, especially for mobile SCR applications, which are characterized by increasingly wider temperature windows.

Table 3
SCR Catalyst Technologies

Catalyst	Temperature Range, °C

Platinum (Pt)   175 - 250
Vanadium (V_2O_5) 300 - 450
Zeolite (high temperature)   350 - 600
Zeolite (low temperature)   150 - 450
Pt Catalysts

At low temperatures, the SCR reactions, Equation (1) to (5), dominate over the Pt catalyst, so NO_x conversion increases with increasing temperature as shown in Figure 4. At about 225-250°C, the oxidation of NH_3 to NO_x and H_2O, Equation (10), becomes dominant. As a result, the conversion versus temperature plot reaches a maximum and begins to fall. To utilize the Pt-based catalyst, one must control the process gas temperature to be above approximately 200°C to avoid NH_4NO_3 formation, Equation (11), but not to exceed about 225°C, where the catalyst loses its selectivity toward the NO_x reduction reaction. This narrow window for temperature control adds expense and complexity to the overall process design. Consequently, the use of this technology has been rather limited.

Vanadia/Titania Catalysts
Medium temperature V_2O_5 based catalysts operate best in the temperature range between 260 and 450° C. This has the obvious advantage of a wider temperature window than Pt. However, NO_x conversion over vanadia also exhibits a maximum followed by a decline where the catalyst loses activity, as shown in Figure 4. NO_x conversion initiates at about 225°C, and rises to a plateau at about 300 - 400°C. Once the temperature exceeds about 425°C, the selectivity is lost and the rate of ammonia oxidation begins to dominate, causing NO_x reduction efficiency to fall.

Upon exposure of the V_2O_5/TiO_2 catalyst to high temperatures, the high surface area _anatase_ TiO_2 irreversibly converts to _rutile_ (with a surface area of less than 10 m^2/g). Normally, this conversion takes place at about 500 - 550°C, but stabilized catalyst formulations have been developed of increased thermal durability. Tungsten trioxide (WO_3) is the most frequently used stabilizer for SCR vanadia/titania formulations. Stabilized V_2O_5/TiO_2 catalysts were reported to be thermally stable up to 700°C. Example data for such catalyst, showing a dramatic loss of activity after aging at 750°C, is presented in Figure 5 [Gieshoff 2000].

Figure 5. Thermal Aging of $V_2O_5/WO_3/TiO_2$ Catalyst
100 hours furnace aging in 10% H_2O, 20 ppm SO_2, air
$V_2O_5/WO_3/TiO_2$ systems became a very common SCR catalyst for stationary sources [Janssen 1997]. Among these three oxides, TiO_2, which plays the role of the high surface area carrier, is used in the highest loading. In homogeneous monoliths, the typical titania content is about 80% [Beretta 1998]. V_2O_5 is believed to be responsible for both NO_x reduction and for the undesired oxidation of SO_2. Its content varies depending on application; in high sulfur applications, the vanadia content can be less than 1%. WO_3, which improves the durability and also increases the acidity of the catalyst, is used at about 10%.

Vanadia/titania catalysts were also developed for mobile diesel engines [Gieshoff 2000]. However, reports on the possibility of vanadium emissions from SCR catalysts [JARI 2004] have raised public health concerns in some countries. Since 2005, vanadium pentoxide (in its orthorhombic crystalline form, which may or may not be present in SCR catalysts) has been listed as a cancer causing chemical

under the Proposition 65 rule in California [OEHHA 2005]. It appears that the development and use of vanadium formulations will continue in Europe, while zeolite catalysts become the preferred option in Japan and in the USA.

Zeolite Catalysts

High Temperature Zeolite. The first zeolite identified as an active SCR catalyst was mordenite. Common mordenites have a well defined crystalline structure with $SiO_2 : Al_2O_3$ ratio of about 10. Manufacturers usually do not disclose the precise chemical composition of the zeolites, so it is not possible to describe them in detail. The zeolites are typically exchanged with metals. Iron-exchanged zeolites were found particularly useful in the SCR application [Chen 1995].

Zeolite SCR catalysts which are commercially available for stationary applications can operate at temperatures up to 600°C [Heck 1994]. When NO_x is present, this catalyst does not oxidize ammonia to NO_x according to Equation (10). Therefore, unlike the Pt and V_2O_5 catalysts, its NO_x conversion continually increases with temperature as shown in Figure 4. The upper temperature limit for this type of zeolite catalysts may be determined by catalyst durability rather than selectivity.

Zeolite-based catalysts may be prone to stability problems when exposed to high temperatures in the presence of water vapor. At exposure temperatures above 600°C, in a high water content process stream, zeolites tend to deactivate by *de-alumination* whereby the Al^{+3} ion in the $SiO_2 - Al_2O_3$ framework migrates out of the structure. This leads to permanent deactivation and, in extreme cases, collapse of the crystalline structure.

Low Temperature Zeolite. A different type of a low temperature zeolite catalyst has been developed for mobile engine applications [Gieshoff 2001][Spurk 2001]. A starting point for this formulation was the Cu-exchanged ZSM-5 zeolite, well known from the extensive lean-NO_x catalyst research conducted in the 1990s. When used as an SCR catalyst, the Cu/ZSM-5 was active in reducing NO_x within the temperature range of about 200-400°C, but its thermal durability was insufficient. New formulations were developed by modifying and ion-exchanging the zeolite with various undisclosed transition metals. The final "low temperature" zeolite catalyst was thermally stable up to 650°C. The normal NO_x reducing activity of this catalyst was low. The formulation has been specifically designed for operation in nitrogen dioxide containing gases, which significantly improved its NO_x conversion and extended the temperature window. In the presence of NO_2, the catalyst yielded better than 90% NO_x reduction over the 150-500°C temperature range.

Other Catalysts

There is ongoing development of improved and new SCR catalyst formulations, especially those for mobile diesel engine applications. One of the reported new formulations is a bi-functional catalyst designed to simultaneously reduce NO_x and oxidize the NH_3 slip (as well as CO and HC) [Hamada 2005]. The vanadia-free catalyst utilizes titania as the NO_x reducing compound, and a precious metal for the oxidation function.

Source of information: http://www.dieselnet.com/tech/cat_scr.html#cat

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Encl. 3: Overview of Materials (--> particulate filter)

Wall-Flow Monoliths

Ceramic wall-flow monoliths are by far the most common type of diesel filters. They have been utilized in majority of commercial diesel filter systems, as well as in numerous research and demonstration projects. Monolithic filters, derived from flow-through supports used for automotive catalytic converters, were developed by Corning in cooperation with partners from the automotive industry [Murtagh 2002]. A patent for that design—issued in 1981—was owned by General Motors [Outland 1981]. The structure of ceramic wall-flow monolith is shown in Figure 2. The channels are alternately plugged at each end in order to force the diesel aerosol through the porous walls. Thus, the walls of the structure act as a filter.

Figure 2. Wall-Flow Monolith Structure
See Wall-Flow Monoliths for more information.

Monolithic filters are made of cordierite—a synthetic ceramic composition of the formula $2MgO-2Al_2O_3-5SiO_2$ that has been developed for automotive catalytic converters. Cordierite is characterized by very low thermal expansion coefficient, which makes the material resistant to extreme thermal cycling. It also exhibits high temperature resistance (~1200°C) and good mechanical strength. Wall-flow monoliths are also made of silicon carbide, SiC. Silicon carbide is characterized by better temperature resistance (~1800°C) than cordierite. Its drawback is higher thermal expansion coefficient and higher cost.

The filtration mechanism in ceramic monoliths is usually a combination of depth and surface (cake) filtration. In the initial phase, diesel particulates are collected in the pores within the walls through inertial and diffusional deposition. With increasing filter load, however, a layer of soot may be build at the surface of the inlet monolith channels. After that layer develops, is acts as a filtration cake.

Wall-flow monoliths are characterized by very good filtration efficiencies, frequently higher than 90%. The cellular design results in compact size of the filter (although a typical monolithic filter would be still much larger than a catalytic converter for the same engine). Both cordierite and SiC monoliths can be coated with catalysts for use in passive filter systems. Drawbacks of monolith filters include relatively high pressure drop and fast pressure drop increase with increasing soot load, which may lead to a complete clogging. For long filter durability, the regeneration process of wall-flow monoliths has to be designed as to eliminate high temperature peaks due to the exothermic soot combustion. Ceramic monoliths may suffer premature thermal damage (melting, cracking) in filter systems where such conditions are not prevented.

Ceramic Fibers

Overview

Various types of high temperature ceramic fibers have been used in numerous designs of diesel filtration media. In one group of designs, fiber filter cartridges are made by winding or otherwise packaging continuous fibers around steel support members. Another method involves making thin ceramic fiber sheets, resembling paper or fabric. Various configurations of filter cartridges are than made using this ceramic fiber paper.

Common regeneration methods of fiber filters include fuel additives, fuel burners, and electric heaters. Due to the difficulties in applying catalyst coatings to ceramic fibers, fiber cartridges usually cannot be used as catalyzed filters. In view of the advantages of passive or "passive-active" filter systems, the

incompatibility with catalysts may present a serious drawback of fiber filters. Fiber filters have been commercialized to a much lesser degree than wall-flow monoliths.

The possibility of emissions of fibers exists with all types of fiber filters. Fiber fragments may be emitted during regular operation, during initial operation period of a new filter, during filter failure, or under other circumstances. Depending on their geometry and other properties, the emitted fibers may be a health issue with this type of filters.

Wound and Knitted Fibers
See Ceramic Fibers and Cartridges for more information.
One of typical fiber filter cartridge designs involves a layer of continuous fibers wound around a perforated metal tube. A number of cartridges in a diesel filter system are arranged in such way that the exhaust gas is forced to flow inside the tubes and through the yarn layer, where diesel particulates are deposited on the fibers. An example of a wound fiber cartridge is the design utilizing Nextel fibers developed by 3M [fig] [Bloom 1995]. A number of other designs have been developed, which utilize knitted fibers [Mayer 1992] or support fiber layers on wiremesh, formed to provide a spiral flow path [Kahlert 1999]. These designs are discussed in detail in the paper on fiber filters.

Regardless of the cartridge design, ceramic fiber filters are deep-bed filters, working through practically pure depth filtration mechanisms. As such, they tend to show a somewhat lower gravimetric filtration efficiency than the wall-flow monoliths, but may still provide high reductions of particle numbers [Mayer 1995]. If used with fuel additives, fiber filters may be more tolerant to ash deposits than monoliths. The ash, however, may cause fiber durability problems at higher temperatures.

Fiber Papers and Fabrics
In an alternative fiber filter design, the fibers are first formed into thin sheets. Most commonly, ceramic fiber "paper" is made in a process generally similar to that used in paper making, often followed by high temperature firing of the media. Many different designs of filter cartridges made of ceramic fiber sheets (papers or fabrics) have been developed. A pleated media diesel filter design, very similar to the typical engine intake air cleaner element, is shown in Figure 3 [Chung 1993]. This and other ceramic fiber paper filters operate mainly as deep-bed filters, but as the amount of captured soot increases, surface filtration mode is also possible.

Figure 3. Pleated Filter Made of Ceramic Fiber Media
High temperature pleated media filters have been also proposed for electrically regenerated traps [Sakaguchi 1999]. Ceramic silicon carbide fibers were chosen as the filter material. The filter media included two layers—coarse and fine—of the SiC "paper" and a wire cloth, which acted as an electric heater to facilitate regeneration. The clean media showed relatively low filtration efficiency of about 65%, which increased to over 90% once the soot load increased. Prototype systems tested on urban buses accumulated 40,000 km.

Composite SiC-coated alumina fiber media and a wall-flow filter element design have been developed by Feetguard [Miller 2002]. The media is based on varying length alumina fibers of diameters on the order of 3 μm. An aqueous slurry is prepared containing the alumina fibers, organic fibers, and a water soluble thermoplastic binder. The slurry is formed into paper-like sheets and dried. These flexible sheets are then formed into cellular, honeycomb-type filter elements shown in Figure 4. Opposite ends of alternate channels of the honeycomb are sealed by high temperature cement, thus forcing the gas flow through the walls. The channels have a triangular cross-section with the length of a side of the triangle between 3 and 5 mm and a channel length in the range of 70 to 350 mm [Haberkamp 2002].

Figure 4. Cellular Wall-Flow Filter Substrate Made of Ceramic Fiber Media
These "green" filter elements are finished by coating with a phenol-formaldehyde resin binder, drying, firing at about 1000°C, followed by the application of final silicon carbide coating through a chemical vapor deposition process. The resulting filter element structure was reported to be stable at temperatures of 650-700°C.

Ceramic Foams

Rigid ceramic foam structures were once widely researched as diesel particulate filters. A schematic of a ceramic foam filter substrate is shown in Figure 5 [Mann 1981]. Ceramic foam filters attract less attention in the more recent literature.

Figure 5. Ceramic Foam Filter
Ceramic foam filters have large, mostly open, circular pores of 250 to 500 μm in diameter and pore density of 20 to 30 pores per cm^2 [Mizrah 1989]. The foam is manufactured by impregnating a polyurethane foam matrix with ceramic paste. The parts are then calcined to decompose the polyurethane and obtain the rigid ceramic structure. The filters can be made, quite similar to the wall-flow monoliths, of either cordierite or silicon carbide. Ceramic foam filters can be also catalyzed [Yoshida 1989].

Inertial deposition is the major filtration mechanism in ceramic foams. Typical filtration efficiencies are relatively low, usually between 60 and 70%. Due to low soot holding capacity, large filter volumes are needed with ceramic foams.

Metal Fiber Filters

Traps made of packages of wire mesh, metal wool, or metal fleece are another example of typical deep-bed filters. The attractiveness of wire mesh filters has been related to their potential compatibility with a variety of regeneration methods, including catalyzing with alumina-based washcoat or electrical regeneration. A disadvantage of many metal fiber substrates—often characterized by void volumes as high as 95%—is a tendency for blow-off of the accumulated soot.

In some designs, the metal was coated with alumina in order to enhance the collection efficiency due to the alumina whiskers on the filter surface. This type of coated steel wool filter was developed by Texaco [MacMahon 1982]. The PM mass collection efficiency in the Texaco filter ranged between 50-70% [Fang 1984]. The collection efficiency initially increased as the particle mass was accumulated, reached a peak, and then decreased. The decrease in efficiency was explained by reentrainment of agglomerates of collected particles; the coarse particle mass fraction leaving the filter increased markedly with time.

Metal fleece for diesel filter applications is being developed by Bekaert [Meinig 1998]. The particle trapping medium is sintered fleece consisting of drawn metal filaments of a medium diameter of 21 μm. The fleece is made of a Fe-Cr alloy with the addition of Y ("FECRALLOY A" by AERE Harwell). Sheets of the fleece are formed into pleated cartridges. An electrically regenerated design was also developed, where the fleece itself is used as a resistive heater [DePetrillo 2002].

Sintered Metal

Sintered metal powder materials have been developed which show high filtration efficiency for diesel particulates. The most common design is based on a stainless steel wiremesh sheet, which is coated with metal powder mixed with additives. Once the coated sheet is sintered, it can be formed into various filter assemblies through standard sheet metal processing techniques, like cutting, stamping, seaming, and welding.

In filters manufactured by Purem, sintered metal sheets are typically cut into annular plates, which are alternately joined along their inside and outside perimeters to form filter structures, as shown in Figure 6 [Purem 2002]. Stamped protrusions ensure that there is always space for gas flow between adjacent sheets.

Figure 6. Flow Direction in Sintered Metal Filter Assembly

Selected properties of Purem sintered metal are listed in Table 2 [Purem 2002]. The mechanical properties are dominated by the wire mesh, the porosity is given through the metal powder and its sintering process.

Table 2
Properties of Sintered Metal Sheets (Purem)

Property	Value
Material Name	Sintered Metal Light
Material Type	1.4845
Weight	2200 g/m^2
Thickness	0.55 mm
Porosity	50%
Mean Pore Size	10 μm
Permeability (Darcy Coefficient)	1.5† μm^2
Heat Conductivity (20°C)	14 W/mK
Specific Heat	500 J/kgK
Thermal Expansion Coefficient (20-1000°C)	18×10^{-7} K^{-1}
Tensile Strength	60 MPa
Young Modulus	14-26† GPa
Elongation at Break	24† %

$\dagger$ - intrinsic material property

Sintered metal filters cannot be catalyzed. They have been tested primarily together with fuel additives [Zelenka 1998] or else with an upstream NO_2 catalyst (CRT configuration). According to some opinions, sintered metal substrates are compatible with additives, showing more resistance against plugging with additive ash than other types of substrates.

Sintered metals have a number of advantages related to the metal material. They can be flexibly fabricated in a variety of shapes to accommodate space constrains. On the negative side, they are characterized by relatively heavy weight.

Other Metal Filters

A number of other metal filter designs have been proposed, including a porous metal substrate made of Ni-Cr-Al alloy [Yoro 1998]. This porous metal media is made of thin sheets (50 - 100 μm) of metallic foam with pores of 150 to 400 μm diameter. Sheets of porous metal media were alternated with electric heater sheets in a particulate filter prototype.

Another filter design, utilizing spirally wound flat sheets of metallic fabric alternated with corrugated sheets of metal foil, is shown in Figure 7 [Ban 1999]. The inlet to the corrugated area is alternately sealed at the opposite ends, making this structure a wall-flow type of filter. As the exhaust gases flow through the metallic fabric, particulates are trapped on the metal filaments and the alumina whiskers.

Figure 7. Metal Wall-Flow Monolith

a - metal fiber fabric detail; b - wall-flow substrate
Pleated Paper Filters
Pleated paper cartridges, which resemble regular engine intake-air cleaners, can be used as disposable diesel filters. Paper filters exhibit excellent, close to 100%, filtration efficiency. However, such systems require that the exhaust gas is cooled. There are two temperature considerations with paper filters: (1) the mechanical durability of the filter media, and (2) the possibility of catching fire by soot accumulated in the filter. The maximum temperature limit of regular filter media varies from 80 to 120°C [Majewski 1993]. Application of such media requires that substantial quantities of heat are dissipated from the exhaust gases, e.g., through the installation of a dedicated exhaust gas cooler [Majewski 1992]. Synthetic papers of increased maximum operating temperature offer only limited advantage, due to the possibility of fire in hot filters which is a critical safety issue. Such high-temperature paper filters had been under development [Wright 1991], but the idea was later abandoned. Other issues with paper filters include generation of solid waste and maintenance intensity.

Paper diesel filters found a limited use in underground coal mining in the USA [Ambs 1992]. Such filters are used on some permissible vehicles which operate in explosive atmospheres. The maximum temperature of exhaust gases discharged from permissible vehicles is limited by safety regulations. On-vehicle exhaust coolers (water scrubbers or heat exchangers) which are used to meet the exhaust temperature requirements make these vehicles compatible with paper diesel filters. It is important that the exhaust gas coolers are equipped with fail-safe controls. Otherwise, fire hazard exists whenever hot exhaust gases enter the filter cartridge.

Source of information: http://www.dieselnet.com/tech/dpf_mat.html#materials

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7/11/2006